

Appendix A

Parameters Used in the Land Application Risk Assessment for Biosolids

Parameter Definition	Abbreviation Used in Calculation of Pollutant Limit	Pathway Where Used (see Table 6)	Source of Further Information
Pollutant Limit Calculated via the Risk Assessment Process:			
(1) The amount of a pollutant that can be applied to a hectare of land without adverse effects	RP	For most pathways (Pathways 1,2,4,6,8, 9,10,11,12,13,14; except 3,5,7)	Appendix B (most parameters); Chapter 4, Boxes 9-14 (RP or RSC parameters)
(2) The concentration of pollutant in biosolids that can be ingested without adverse effects	RSC	(Pathways 3,5,7)	
RP & RSC used for Pathways 1–11:			

$$RP \text{ or } RSC = \frac{\text{Allowable Dose of Pollutant}}{\text{Plant Uptake} \times \text{Dietary Consumption} \times \text{Food Production parameters (whichever is relevant)}}$$

or

RP for Pathways 12 (surface water [sw]), 13 (air) and 14 (groundwater [gw]) based on:

$$RP = \frac{\text{Parameters for pollutant concentration (includes health parameters) in eroding soil [for sw] or air emissions [for air] or beneath site [for gw]} \times \text{loss rate parameter [for sw and gw]}}{\text{Fraction of total loss parameter (erosion [for sw], volatilization [for air], or leaching [for gw])}}$$

The parameters used in the risk assessment calculations are described below:

Parameter Definition	Abbreviation Used in Calculation of Pollutant Limit	Pathway Where Used (see Table 6)	Source of Further Information
Health-Based Parameters Used in Risk Assessment Calculations:			
<i>For People:</i>			
Amount of pollutant ingested by humans without expectation of adverse effects (based on RfD or q_1^* , BW, RL, RE, TBI, see below)	RIA	Pathways 1,2,3,4,5	Chapter 4, Boxes 9-11
— <i>Risk reference dose (RfD)</i> —daily intake of chemical that during an entire lifetime appears to be without appreciable risk on the basis of all the known facts at the time (Lu, 1983); or <i>cancer potency value (q_1^*)</i> —conservative quantitative indication of the likelihood of a pollutant inducing or causing cancer during the lifetime of a continuously exposed individual	RfD or q_1^* , or an RDA when there was no RfD for a pollutant	All human pathways (Pathways 1,2,3,4,5, 12,13,14)	Chapter 2, Box 3
— <i>Cancer risk level</i> —the probability that one additional cancer case could be expected to occur in an exposed population of a certain size (e.g., the RL could be set at 1×10^{-4} = 1 add. cancer case in a population of 10,000 exposed individuals)	RL	In conjunction with q_1^* s (Pathways 1,2,3,4,5,12,13,14)	Chapter 3, text
— <i>Human body weight (kg)</i> —average adult male body weight of 70 kg (154 lbs) was used to represent a “lifetime” weight, since the RfD/ q_1^* represents a lifetime dose (70 years)	BW	All human pathways (Pathways 1,2,4,5,11,12,13,14)	
— <i>Child</i> : average body weight—16 kg (35 lb) for child (ages 1-6) with respect to agricultural land and 19 kg (42 lb) with respect to nonagricultural land (also see Appendix B)	BW	Pathway 3	
— <i>Relative effectiveness of exposure</i> —accounts for differences in bioavailability and routes of exposure (e.g., inhalation vs. ingestion); because of limited data, this value was conservatively set at 1	RE	Pathways 1,2,3,4,5	
— Allowable (“reference”) concentration of pollutant in human diet ingested as a result of animal tissue consumption (based on RIA, and UA, DA, FA, see below)	RF	Humans eating animal products (Pathways 4,5)	
— Allowable (“reference”) intake of pollutant, based on q_1^* and RL, or RfD (RL/ q_1^* or RfD—background intake)	RI	Surface water (Pathway 12)	Chapter 4, Box 14
— Allowable (“reference”) water concentration of a pollutant in surface water, air, or ground water	RC _{sw} RC _{air} RC _{gw}	Surface water, air, or ground-water pathways (Pathways 12,13,14)	
— Allowable (“reference”) concentration of pollutant in:		Surface water or ground water	Chapter 4, Box 14
soil eroding into the surface water stream	RC _{sed}	(Pathway 12)	
soil eroding from the biosolids application area (SMA)	RC _{sma}	(Pathway 12)	
leachate beneath the land application site	RC _{lec}	(Pathway 14)	

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Health-Based Parameters (continued):			
<i>For Animals:</i>			
Allowable ("reference") concentration of pollutant in animal diet ingested as a result of eating plants, based on:	RF	Animals eating plants (Pathways 6,7)	Chapter 4, Box 12
— Maximum pollutant intake level in animal diet without observed toxic effect on most sensitive or most exposed species (threshold pollutant intake)	TPI	For animal toxicity (Pathways 6,7)	
Environmental Parameters:			
<i>For Soil Organisms and Soil Concentration Values:</i>			
Pollutant concentration in soil considered to have no adverse effects on soil organisms, or minimal effects on animals or humans in pathways where people or animals are the target organism (e.g., for degradable organics, or when diet is soil/soil organisms)	RLC	For Pathways 1,2,4,9,10	
<i>For Plants:</i>			
Toxicity based on:			
— (1) <i>Phytotoxicity threshold</i> —Concentration of a pollutant in plant tissue associated with a 50% retardation in growth of young vegetative tissue based on studies of plants grown in pots of metal amended soil or nutrient solution	PT ₅₀	For plant toxicity (Pathway 8)	Chapter 3, text (see Pot/Salt vs. Field Studies, Sludge Binding, and Ecological Risk Assessment); Chapter 4, Box 13
or			
— (2) <i>Threshold pollutant concentration</i> in plant tissue assoc. with phytotoxicity, based on lowest observed adverse effect level (LOAEL) of the most sensitive/most exposed plant species in field soils	TPC	For plant toxicity (Pathway 8)	Chapter 3; Chapter 4, Box 13
The most limiting number from approaches (1) and (2) above was used to set the pollutant limit for Pathway 8.			
Dietary Consumption Parameters:			
— Daily consumption by humans of different food groups grown on land amended with biosolids	DC	Humans eating plants (Pathways 1,2)	Chapter 3, text; Chapter 4 (cadmium example)
Daily human consumption of different types of animal products	DA	Humans eating animal products (Pathways 4,5)	
— Rate of soil ingestion by children	I _s	Toxicity to child (Pathway 3)	Chapter 3, text Chapter 4, Box 11
— Daily consumption of:			
fish	I _f	Surface water (Pathway 12)	Chapter 4, Box 14
water	I _w		

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Parameters for Fraction of Diet Produced on Biosolids-Amended Land:			
— Fraction of different food groups assumed to be grown on land amended with biosolids	FC	Humans eating plants (Pathways 1,2)	Chapter 4 (cadmium example)
— Fraction of different animal products assumed to be raised on forage grown on biosolids-amended soils	FA	Humans eating animal products (Pathways 4,5)	
— Fraction of animal diet that is biosolids	FS	Animals eating biosolids (incl. animal products eaten by humans) (Pathways 5,7)	
— Fraction of diet comprised of soil organisms	FD	Animals (soil organism predators) eating soil organisms (Pathway 10)	
Parameters for Plant Uptake of Pollutant:			
— <i>Plant uptake slope</i> for pollutants from soil/biosolids	UC	Humans and animals eating plants; plants themselves (Pathways 1,2,4,6,8)	Chapter 3, text; Chapter 4 (cadmium example)
— Uptake factor relating pollutant concentration in each animal product to pollutant concentration in forage crop/animal diet consumed by the animal	UA	Humans eating animal products (Pathways 4,5)	
Loss-Factor Parameters:			
— <i>First-order loss rate constant</i> —accounts for amount of organic pollutant lost to degradation, leaching, and/or volatilization, based on half-life data	k	For most degradable organic pollutants (Pathways 1,2, 4,5,10)	Chapter 4, Box 10
— <i>Mass balance of pollutant loss</i> —calculates relative rates at which a pollutant is removed (lost) from a site through soil erosion, leaching, volatilization, and/or degradation	K	Surface water, air, ground water (Pathways 12,13,14)	Chapter 4, Box 14
— Mass balance of pollutant loss—calculates fraction of total loss caused by volatilization	f _{vol}	Air (Pathway 13)	
— Mass balance of pollutant loss—calculates fraction of total loss caused by leaching	f _{lec}	Ground water (Pathway 14)	
— Estimated rate of soil loss for the biosolids management area (SMA)	ME _{sma}	Surface water (Pathway 12)	Chapter 4, Box 14
— Estimated rate of soil loss for the watershed	ME _{ws}	Surface water (Pathway 12)	Chapter 4, Box 14
— Fraction of total cumulative loading lost in a human lifetime (inorganics)	f _{ls}	Surface water (Pathway 12)	
— Mass of pollutant at end of a human lifetime (inorganics)	M _{LS}	Surface water (Pathway 12)	

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Background Parameters:			
— <i>Total background intake rate</i> of pollutants from sources of exposure other than biosolids (e.g., from drinking water, food, air)	TBI	All human food chain pathways (Pathways 1,2,3,4,5)	Chapter 4, Boxes 9-11
— Background concentration of pollutant in soil	BS	For animal (incl. soil organism) toxicity (Pathways 7,9,10)	
— Background concentration of pollutant in plant tissue	BC	For animal and plant toxicity (Pathways 6,8)	Chapter 4, Boxes 12, 13
Bioavailability and Bioaccumulation Parameters:			
— Fractional toxicity of pollutants in biosolids (compared to metal salt-amended diets)	BAV	Animals eating soil organisms (Pathway 10)	Chapter 3, text (see Ecological Risk Assessment)
— Pollutant-specific bioconcentration factor	BCF	Surface water (Pathway 12)	Chapter 4, Box 14
— Pollutant-specific food chain multiplier	FM		
Exposure Through Inhalation:			
Allowable concentration of pollutant in dust, based on:	MDC, based on: (Pathway 11)		
— NIOSH air quality criteria for the pollutant	NIOSH		
— ACGIH total dust standard	TDA		
— Ratio relating the concentration of pollutant in ambient air (at HEL's location) to the rate at which the pollutant is emitted from biosolids-amended soil	SSR	(Pathway 13)	
— Reference annual flux ^a of pollutant emitted from the site	RF _{air}	(Pathway 13)	
Additional Parameters Specific to Surface Water:			
— Density of water	P _w	(Pathway 12)	
Partition factors (used to derive concentration of pollutant in surface water):		(Pathway 12)	
— partition coefficient between solids and liquids within the stream	KD _{sw}		
— percent liquid and solids in the water column	P _l , P _s		
Additional Parameters Specific to Ground Water:			
— Ratio of predicted concentration of pollutant in well to concentration in leachate	f _{wel}	(Pathway 14)	
— Reference annual flux ^a (net recharge in m/yr) of pollutant beneath the site	RF _{gw}	(Pathway 14)	

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Additional Parameters Specific to Ground Water (continued):

— Length of square wave ^b in which maximum total loss rate of pollutant depletes total mass of pollutant applied on site (inorganics)	TP	(Pathway 14)	
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^aFlux is the amount of air or ground water flowing across a given area per unit of time (RF_{gw}/f_{lec} = application rate [RP]).

^bSquare wave refers to a pulse of constant magnitude representing maximum annual pollutant loss (kg/ha · yr) occurring over the 300-yr simulation model. Used in VADOFT model to predict concentration of pollutant at the water table.